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Collaborative Decision Systems Project Summary of Technology Developments for Human-Robotics Interactions

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Abstract

Future manned exploration will involve increasingly complex missions in space and on planetary surfaces. Flight crews will need to be largely self-reliant in routine operation with ground support providing rapid expert consultation and ad hoc support. Creating and executing such control strategies requires machine intelligence, coupled tightly with human intelligence, to become an integral part of future flight systems for both manned and unmanned missions. This means that both the systems and sub-systems fielded by the exploration initiative will need to be “smarter” and that these automated systems, and the human crew, will need to function as a well-integrated robust team.

The Collaborative Decision Systems (CDS) Project addressed these challenges by creating technology for automating both nominal operations and health management, and technologies for merging automated systems and human crews into functional self-reliant teams. The CDS Project performed low- to mid-TRL inter-disciplinary research and technology development integrated across multiple research groups, principal investigators, and NASA centers. The development and integration resulted in an integrated technology demonstration that modeled a ‘day on the surface’ that featured an astronaut, 2 autonomous rovers, and a habitat crew.

Technologies developed and utilized in the integrated scenario included; instrument and Tool placement; flexible command cycles; real-time EVA monitoring and collaboration; voice commanded device control; worksite navigation and planning; and integrated data management.

Numerous factors drove the design. The planner-robot-agent system must accept requests from multiple crew members and provide a mechanism for resolving conflicts between them. A single robot operator (by assumption, a crew member inside the

habitat) must be able to oversee the system and provide input where necessary, but should be involved in the EVA only when needed. Space-suited crew members must be able to verbally issue and confirm high-level goal requests. All crew member activities and robot requests must be coordinated in a natural and timely manner. Finally, the system must adapt to faults and off-nominal resource (time and energy) issues.

We introduced a framework for a system that allows for the multiple crew members, both in a habitat and on EVA, to work together with multiple robots under the control of a single centralized planner program and overseen by a single operator. The system is designed for tasks that can be decomposed into loosely coupled sub-tasks that each agent (person or robot) can execute. By using a distributed multi-agent architecture, people, robots, tools and instruments, interfaces can be integrated into a coherent data and workflow system.

Research issues in this project included dynamic re-planning and plan repair in response to new task requests or faults, efficient user interfaces and workflows, and visual target tracking for sensor placement.

The demonstration required aggressive integration of many components and a very large team (25+ people) in a short time (8 months). Publications and AV material are currently in production.

This paper summarizes the individual technology developments, the integration process, the results, lessons learned, and future directions for related research and development.